Vision Research 102 (2014) 64–70

Contents lists available at ScienceDirect

Vision Research

journal homepage: www.elsevier.com/locate/visres

Vergence eye movements in patients with schizophrenia

Mark S. Bolding [a,c], Adrienne C. Lahti [b], David White [b], Claire Moore [a], Demet Gurler [a], Timothy J. Gawne [c], Paul D. Gamlin [d,*]

[a] Department of Radiology, University of Alabama at Birmingham, 619 19th Street South, GSB 315, Birmingham, AL 35294-0017, USA
[b] Department of Psychiatry, University of Alabama at Birmingham, 1530 3rd Avenue South, SC 501, Birmingham, AL 35294-0017, USA
[c] Department of Vision Sciences, University of Alabama at Birmingham, 1530 3rd Avenue South, WORB 186, Birmingham, AL 35294-0017, USA
[d] Department of Ophthalmology, 1103 Shelby Building, 1825 University Blvd., University of Alabama at Birmingham, Birmingham, AL 35294, USA

ARTICLE INFO

Article history:
Received 4 June 2014
Received in revised form 22 July 2014
Available online 1 August 2014

Keywords:
Schizophrenia
Vergence
Convergence insufficiency
Smooth pursuit

ABSTRACT

Previous studies have shown that smooth pursuit eye movements are impaired in patients with schizophrenia. However, under normal viewing conditions, targets move not only in the frontoparallel plane but also in depth, and tracking them requires both smooth pursuit and vergence eye movements. Although previous studies in humans and non-human primates suggest that these two eye movement subsystems are relatively independent of one another, to our knowledge, there have been no prior studies of vergence tracking behavior in patients with schizophrenia. Therefore, we have investigated these eye movements in patients with schizophrenia and in healthy controls. We found that patients with schizophrenia exhibited substantially lower gains compared to healthy controls during vergence tracking at all tested speeds (e.g. 0.25 Hz vergence tracking mean gain of 0.59 vs. 0.86). Further, consistent with previous reports, patients with schizophrenia exhibited significantly lower gains than healthy controls during smooth pursuit at higher target speeds (e.g. 0.5 Hz smooth pursuit mean gain of 0.64 vs. 0.73). In addition, there was a modest ($r \approx 0.5$), but significant, correlation between smooth pursuit and vergence tracking performance in patients with schizophrenia. Our observations clearly demonstrate substantial vergence tracking deficits in patients with schizophrenia. In these patients, deficits for smooth pursuit and vergence tracking are partially correlated suggesting overlap in the central control of smooth pursuit and vergence eye movements.

1. Introduction

Previous eye tracking studies in patients with schizophrenia have reported abnormalities in their eye movements; specifically, smooth pursuit and antisaccades (for reviews see Levy et al., 1994; Rommelse, Van der Stigchel, & Sergeant, 2008; Smyrnis, 2008; Turetsky et al., 2007). The smooth pursuit deficits associated with schizophrenia were first observed by Diefendorf and Dodge (1908) and, since then, smooth pursuit eye movement dysfunction has consistently been found in individuals with schizophrenia (O'Driscoll & Callahan, 2008; Smyrnis, 2008; Turetsky et al., 2007). However, under normal viewing conditions, targets move not only in the frontoparallel plane but also in depth, and tracking requires both smooth-pursuit eye movements, guided primarily by retinal slip velocity, as well as vergence eye movements guided primarily by binocular disparity, blur, and motion-in-depth signals. Psychophysical observation in humans (Rashbass & Westheimer, 1961; Regan, Erkelens, & Collewijn, 1986; Semmlow, Yuan, & Alvarez, 1998), and electrophysiological studies in non-human primates (Gamlin & Clarke, 1995; Gamlin & Yoon, 2000; Gamlin, 2002) suggest that these two eye movement subsystems are relatively independent of one another. Nevertheless, the cortical substrates of vergence eye movements include areas such as the frontal eye fields (FEF) (e.g. Fukushima et al., 2002, 2004; Gamlin & Yoon, 2000; Gurler et al., 2011), which have been implicated in the smooth pursuit deficits in schizophrenia (Goldman-Rakic & Selemon, 1997; Holzman, 2000; Levy et al., 2010). Based on this, it seems plausible that patients with schizophrenia might exhibit vergence tracking deficits. However, to the best of our knowledge, there have been no reports on vergence tracking performance in patients with schizophrenia. Therefore, we investigated dynamic aspects of vergence tracking in healthy controls and patients with schizophrenia.

2. Methods

Twenty-four subjects with schizophrenia and schizoaffective disorder (SZ) were recruited from the outpatient psychiatry clinic

* Corresponding author. Fax: +1 (205) 975 7394.
E-mail address: pgamlin@uab.edu (P.D. Gamlin).

http://dx.doi.org/10.1016/j.visres.2014.07.008
0042-6989/

at The University of Alabama at Birmingham to participate in this study. Twenty-three healthy controls (HC), matched on age, gender, ethnicity, and parental occupation, were recruited by advertisement in flyers and the university's newspaper. Exclusion criteria were major medical conditions, substance abuse within six months of examination, previous serious head injury, a neurological disorder, and loss of consciousness for more than 2 min. The study was approved by the Institutional Review Board of the University of Alabama at Birmingham in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans, and all subjects gave written informed consent. Before signing consent, each SZ subject completed an Evaluation to Sign Consent Form.

Diagnoses were established using subjects' medical records and the Diagnostic Interview for Genetic Studies (DIGS) (Nurnberger et al., 1994). General cognitive function was characterized by the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) (Randolph et al., 1998). The Brief Psychiatric Rating Scale (BPRS) (Overall & Gorham, 1962) and its positive and negative subscales were used to assess mental status and symptom severity.

Participants were also excluded during vision screening if they had acuity of less than 20/40 in either eye, more than 2 lines of difference in visual acuity between the eyes, or lack of stereopsis. Each subject was examined by the same doctor who was masked to the patient's psychiatric diagnosis. Three participants (SZ = 1) were excluded during vision screening and 4 (SZ = 3) withdrew or were lost to follow up. Forty participants, 20 SZ and 20 HC, completed the study and were included in the final analyses.

2.1. Binocular vision and vergence testing

All visual measures were taken with the subject's habitual prescription in place. Distance visual acuity was measured in each eye with a projected Snellen chart at 20 feet. Near visual acuity was screened in each eye with a 20/30 isolated line of letters. Binocular vision testing included fixation disparity (Saladin card), ocular alignment with cover test at distance and near, near point of convergence break (NPC) and recovery, positive fusional vergence at near break and recovery (prism bar), stereo acuity (Randot Stereo), accommodative amplitudes (push-up) for non-presbyopes, and distance and near auto-refraction.

Based on these static measures, we have previously reported for this cohort of patients that their mean NPC (5.5 cm) was not significantly different from healthy controls (4.4 cm), and that they did not exhibit convergence insufficiency more frequently than healthy controls (Bolding et al., 2012).

2.2. Eye tracking tasks

All of the eye tracking experiments were performed in a darkened room. Each task lasted 60 s and there was a 20 s gap between each task. The task order was randomized for each participant. A chin rest and pads placed against the temples were used to minimize head movement. The chin rest was adjusted so that the bridge of the participant's nose (midpoint between the eyes) was level with the vergence tracking target and the center of the CRT described below. Eye movement data was collected with a head mounted, dual camera, video eye tracker with a 500 Hz sample rate (Eyelink II, SR Research). Head movement was tracked so that residual head movement could be removed from the eye tracking signal. Eye tracking was calibrated at the start of the session using a 9-point calibration procedure and a 1-point drift correction was performed before each task.

For the smooth pursuit task in the frontoparallel plane, we used a CRT with a flat screen set at a refresh rate of 75 Hz. The screen was 60 cm from the participant. The target was a 1° diameter white disk with a 0.2° black dot in the center (Fig. 1B). The target was presented on a black background and the brightness was matched to that of the vergence target described below. The smooth pursuit target moved horizontally with a constant speed, triangular waveform over a range of 14°. The speed of the target was 5.6°/s, 14°/s, or 28°/s.

The vergence tracking target was mounted on the carriage of an HP 7044A XY flatbed recorder. This recorder has a 28 × 43 cm range of travel, accuracy of 0.2% full-scale, acceleration of 5080 cm/s^2 and a slew rate of 104 cm/s. The target was a small disk of holographic diffuser material with a black dot inscribed in the center (Fig. 1A). It was illuminated with a white LED via a fiber optic bundle. In order to match the pursuit target, the vergence target was sized so that it would form a 1° disk at the distance of the CRT. The target moved along a line that passed through the bridge of the participants nose and the center of the CRT described above. During the vergence tracking task, the target motion had a constant speed, triangular waveform in depth over a range of 20 cm starting from 30 cm away from the subject. The speed of the target was 2 cm/s, 4 cm/s, or 10 cm/s. With this arrangement, because the target speed through space was constant, the angular speed varied with target distance. However, if the angular speed is held constant, the target appears to decelerate as it approaches the subject and accelerate as it recedes. The average angular speed of the target (i.e. the angular difference between 10 cm and 30 cm divided by half the period) was 2.2, 4.4, or 11°/s respectively for a subject with a 6 cm inter-pupillary distance.

2.3. Data analyses

For initial analysis, eye movements were decomposed into saccadic and slow components. Saccades were identified using velocity, and acceleration thresholds of 22°/s and 4000°/s^2 respectively. Since we were interested in saccades that occurred during pursuit and tracking eye movements that could exceed 22°/s, the velocity threshold was increased by the average velocity of the eye over the preceding 40 ms (up to a limit of 60°/s).

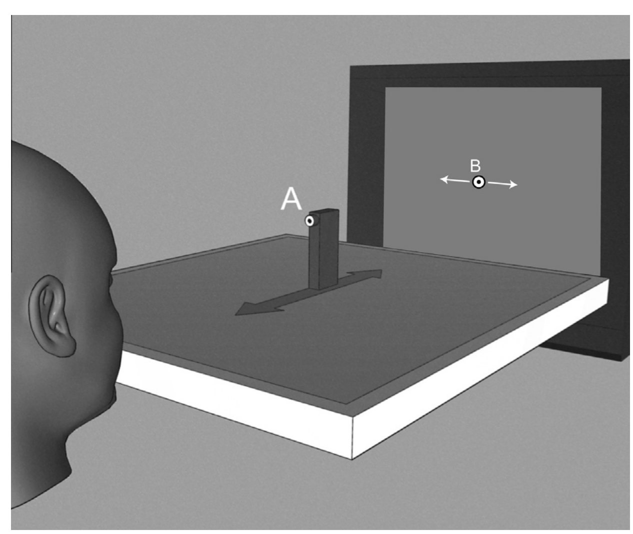

Fig. 1. Illustration of vergence pursuit and smooth pursuit stimuli used in the dynamic eye movement experiment. The arrows represent the direction of target motion and were not presented to the participant during the experiment. (A) Vergence tracking target. The white circle represents the holographic diffuser with inscribed black dot backlit by a white LED. The vergence target is mounted on the moving chassis of an *X–Y* plotter. (B) Smooth pursuit target. The white circle with a centered black dot represents the smooth pursuit target, which was presented on the flat screen monitor. Vergence tracking and smooth pursuit targets were presented in separate trials.